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Giampiero ANTONELLI et al	)	Group Art Unit: Unassigned
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Filed: October 31, 2003	)	Confirmation No.: Unassigned
For: A NON-DESTRUCTIVE METHOD OF DETECTING DEFECTS IN BRAZE-REPAIRED CRACKS	)	

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The benefit of the filing date of the following prior foreign application in the following foreign country is hereby requested, and the right of priority provided in 35 U.S.C. § 119 is hereby claimed:

European Patent Application No. 02405932.1

Filed: October 31, 2002

In support of this claim, enclosed is a certified copy of said prior foreign applicaiton. Said prior foreign application was referred to in the oath or declaration. Acknowledgment of receipt of the certified copy is requested.

Respectfully submitted,

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The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. Patent application No. Demande de brevet n°

02405932.1

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

R C van Dijk

Anmeldung Nr:
Application no.: 02405932.1
Demande no:

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Anmelder/Applicant(s)/Demandeur(s):

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

A non-destructive method of detecting defects in braze-repaired cracks

In Anspruch genommene Prioriät(en) / Priority(ies) claimed /Priorité(s) revendiquée(s)
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A non-destructive method of detecting defects in braze-repaired cracks

TECHNICAL FIELD

The invention relates to a non-destructive method of detecting and quantifying subsurface defects in an article after brazing according to the independent claim.

STATE OF THE ART

The wide use of single crystal (SX) and directionally solidified (DS) components allows an increased turbine inlet temperature and therefore an increased turbine efficiency as well. Alloys, specially designed for SX/DS casting, were developed in order to make maximum use of material strength and temperature capability. During operation of such components under high temperature conditions, various types of damages can occur. For example, cracks can result from thermal cycling and foreign object impact. In addition, cracks and inclusions my be incurred during manufacture. Because the cost of the components formed from high temperature nickel base superalloys is rela-

tively high, it is usually more desirable to repair these components than to replace them.

The following state of the art methods for repairing high temperature superalloys are generally known:

US 5,732,467 discloses a method of repairing cracks on the outermost surface of an article having a directionally oriented microstructure and a superalloy composition. The repairing is done by coating the cleaned crack surface with a material featuring the same material composition as said article. Thereby the coated crack surface is subjected to an elevated temperature and isostatic pressure over a period of time sufficient to repair the crack surface without changing the crystalline microstructure of the parent article.

In addition, a number of alternative methods of brazing for repairing cracks or gaps are known. US-5,666,643 discloses a braze material for repairing an article, in particular components made from a cobalt and a nickel-base superalloy, such as gas turbine engine parts. The braze material is composed of particles featuring a high melting temperature which are distributed within the a braze alloy. These particles could be of single crystal, directionally solidified, or equiaxed microstructure.

Existing NDE-techniques have limited capabilities to quantitatively characterise any remaining subsurface brazing defect or in complex geometries like gas turbine blades and vanes. Especially Eddy Current techniques of prior art can not be applied on geometries with locally changing wall thickness in the range of the penetration depth of the eddy current sensor. They are not able to give quantitative information on defect size and in-depth location in varying geometries as Burke, S.K, G., 2001, "Crack depth measurement using Eddy-Current NDE", presented at Destructive Testing, Sep 17 – 21, 2001, Brisbane, AUS discloses.

SUMMARY OF INVENTION

It is the aim of the present invention to find a non destructive testing method for the quality control of high temperature brazed cracks or gaps made of article made of high strength non magnetisable materials such as blades or vanes of gas turbines made from a Nickel base superalloy.

This objective is solved by method of detecting and quantifying subsurface defects in an article made of high strength non magnetisable materials after the use in a high temperature environment, the article exhibiting a crack or gap on a surface, the method comprising the steps of

(a) the crack or gap is brazed and

(a) after the brazing operation any remaining braze defect or subsurface crack is detected and quantified by means of a multifrequency eddy current system.

Thereby, it is possible to determine the distance of remaining braze defects or subsurface cracks after brazing from the accessible surface of the component and the depth of the remaining crack, gap or defect. Dependent on the measured extent of the remaining crack after brazing a decision can be made concerning the fulfillment of quality requirements of the braze.

In addition, the surface of the crack or gap may be cleaned from oxides by using any means known in the state of the art such as Floride Ion Cleaning (FIC), other halide cleaning, hydrogen cleaning, salt bath cleaning, any combination thereof or other means, which is widely known in state of the art.

In one embodiment of the present invention the method is applied to blades or vanes of gas turbines made from a Nickel base superalloy.

SHORT SUMMARY OF DRAWINGS

The invention is illustrated by the accompanying drawings, in which

Fig. 1 shows a turbine blade,

Fig. 2 shows a crack on the external surface of the blade,

Fig. 3 shows a brazed repaired crack,

Fig. 4 shows a crack on the internal surface of the blade

Fig. 5 shows a schematic drawing of a multifrequency eddy current system and

Fig. 6 shows a not fully brazed crack in a component.

The enclosed drawings show only the parts important for the invention.

PREFERRED EMBODIMENT OF THE INVENTION

The invention relates to a method for the quality control of brazed cracks or gaps in a single crystal article 1 made of a Nickel base superalloy. Nickel base superalloys are known in the state of the art, e.g. from the document US 5,888,451, US 5,759,301 or from US 4,643,782, which is known as "CMSX-4". As an example Fig. 1 shows an article 1 such as blades or vanes of gas turbine engines, the gas turbine blade comprising a root portion 2, a platform 3 and a blade 4 with an internal cavity 5, not shown in Fig. 1, and cooling holes 6. The component 1 exhibits cracks 8 and gaps somewhere on an external surface 7 after being exposed to the hot gases of the gas turbine.

As shown in detail and in way of an example in Fig. 2 the external surface 7 of the component 1 exhibits a crack 8 which has to be repaired. As a preparation before applying the method of brazing, a protective coating such as MCrAlY or thermal barrier coating (TBC), has to be removed by a process of acid stripping, grit blasting or mechanical grinding. At the same time this method also cleans the surface layer of the parent material from unwanted oxides, debris, corrosion products or other contaminants. In addition, the surface of the crack or gap may be cleaned from oxides by using any means known in the state of the art such as Floride Ion Cleaning (FIC), other halide cleaning, hydrogen cleaning, salt bath cleaning, any combination thereof or other means, which is widely known in state of the art. The FIC process removes the stable Al_2O_3

oxides and depletes Al from the surface, thereby improving the braze flow and th repair of the cracked components. Th process subjects the oxidized (and sulphidized) components to a highly reducing gaseous atmosphere of hydrogen and hydrogen fluoride at high temperatures, which may vary from 900°C to 1000°C. Such FIC-processes are disclosed, for example, in EP-B1-34041, US-4,188,237, US-5,728,227 or in US-5,071,486. After successful completion of the brazing method according the invention, the component will be recoated.

The crack 8 is subsequently repaired by any kind of brazing known from the state of the art and using an appropriate brazing filler material 9. The result is shown in Fig. 3. In a length L the crack 8 is repaired by the brazing operation in an adequate manner and the brazing material 9 filled the crack 8 properly, whereas other locations shows braze defects 10. The remaining subsurface crack 10 has a depth of x. It may be that any kind of other subsurface braze defect 10 occur during the brazing operation. Thus, the remaining subsurface cracks or braze defects 10, which were not properly filled with braze material 9 during the repair operation, will be detected an quantified by any means of a multifrequency eddy current system.

As an example such a multifrequency eddy current system as described is described in Antonelli, G., Crisafulli, P., Tirone, G., 2001, "Qualification of a Frequency Scanning Eddy Current Equipment for Nondestructive Characterization of New and Serviced High-Temperature Coatings," ASME paper No. 2001-GT-0419 and Antonelli, G., 2002, "Non-Destructive Condition Assessment of MCrAlY Coatings", presented at Turbine Forum on Advanced Coatings for High Temperatures, Nice, France. This system was developed for non-destructive condition assessment of new and service exposed high-temperature coatings applied on the hot gas-path components of land-based gas turbines.

A schematic view of the system is given in Fig. 5. It is a portabl system consisting of following modules:

- Probe with combined or separated transmit-receiver coils,
- Eddy current frequency scanning rang from 10 kHz to 10 MHz,
- Feeding and conditioning unit with high sensitivity and high stability,
- Computer based data analysis unit and
- Display unit

The system fully exploits the capabilities of multiple-frequency eddy current techniques in the characterisation of multiple-layer materials, based on the evaluation of even quite small differences in the electrical conductivity values of the different layers.

The idea of applying the eddy current system to the problem of subsurface crack characterisation relies on an assumption strengthened by initial tests, i.e. the possibility to approximate the local reduction in the effective conductivity due to crack presence, with a conductivity reduction in an horizontal layer of the test material. The estimation of the interface positions L1, L2 and conductivity values $\sigma1$, $\sigma2$, $\sigma3$ of each layer, given by the eddy current system, can be directly correlated with crack parameters such as: ligament thickness (crack distance from surface) L, crack depth x (see Fig. 3) There is no requirement of a calibration procedure on the specific samples to be tested.

Typical geometries of cracks for an application of the present invention are shown Fig. 3 and Fig. 4.

Fig. 6 shows a not fully brazed crack 10 in a component. The graphical comparison between real crack geometry and estimation by the eddy current system of crack dimensions is shown. The layer where eddy current analysis placed the discontinuity is marked with a dotted line.

REFERENCE LIST

1	Article
2	Root portion
3	Platform
4	Blade
5	Cavity
6	Cooling holes
7	External surface of article 1
8	Crack
9	Brazing material
10	Braze defect or subsurface crack
x	Crack depth
L	Ligament thickness, crack distance from surface 7

CLAIMS

1. A method of detecting and quantifying subsurface defects (10) in an article (1) made of high strength non magnetisable materials after the use in a high temperature environment, the article (1) exhibiting a crack (8) or gap on a surface (7), the method comprising the steps of
   (a) the crack (8) or gap is brazed and
   (b) after the brazing operation any remaining braze defect or subsurface crack (10) is detected and quantified by means of a multifrequency eddy current system.

2. The method according to claim 1, wherein the distance of the braze defect or subsurface crack (10) from a surface (7) and the depth of the defect (10) is determined.

3. The method according to claim 1 or 2, wherein dependent on the measured extent of the remaining braze defect or subsurface crack (10) after brazing a decision is made concerning the fulfillment of quality requirements of the braze.

4. The method according to claim 2, wherein local variations of the thickness of the component in the range of the penetration depth of the eddy currents is suppressed as an interfering quantity.

5. The method according to claim 1 or 2, wherein the surface of the crack (8) or gap is cleaned from oxides before applying the method.

6. The method according to any of the claims 5, wherein a Flour-Ion-Cleaning-Method is used for cleaning the surface before applying the process.

7. The method according to any of the claims 1 to 6, wherein the method is applied to blades or van s of gas turbines made from a Nickel base superalloy.

ABSTRACT

It is disclosed a method of detecting and quantifying subsurface defects (10) in an article (1) made of high strength non magnetisable materials after the use in a high temperature environment. A crack (8) or gap on a surface (7) of the article (1) is brazed and after the brazing operation the crack (8) or any remaining braze defect or subsurface crack (10) is detected and quantified by means of a multifrequency eddy current system.

(Fig. 3)

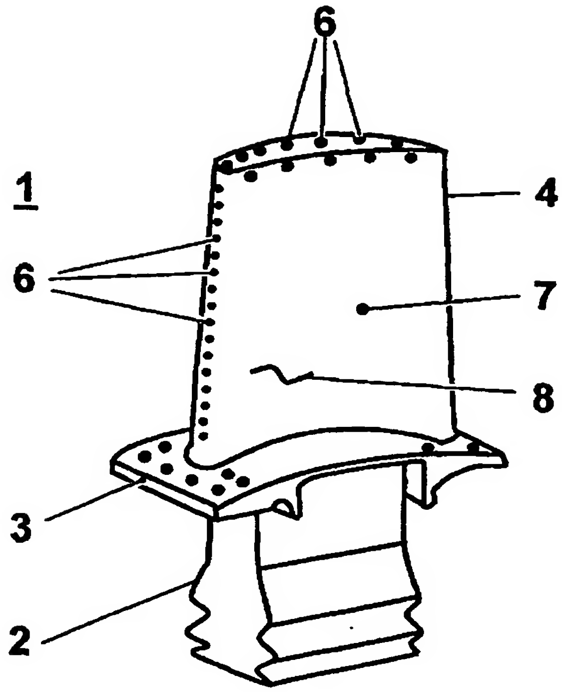

Fig. 1

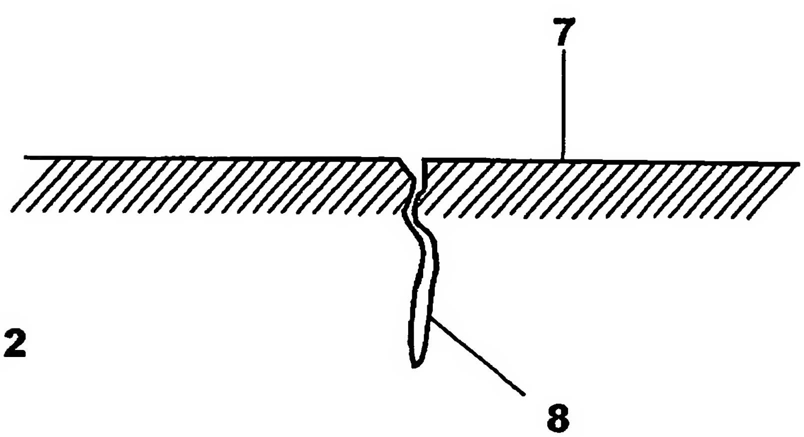

Fig. 2

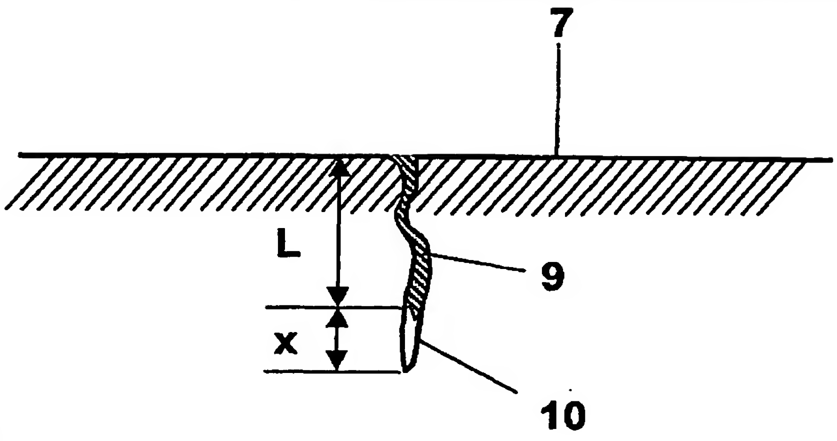

Fig. 3

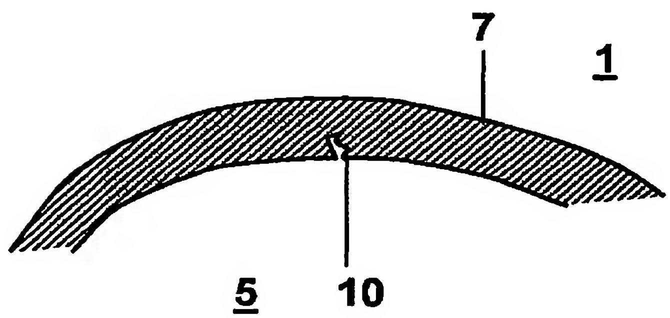

Fig. 4

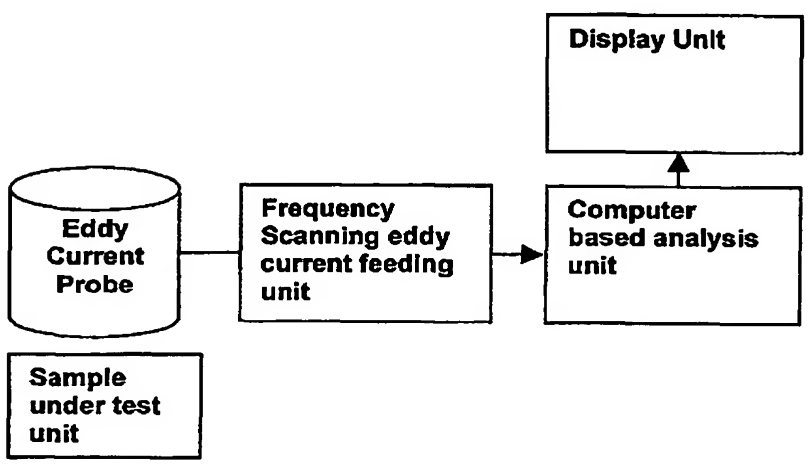

Fig. 5

B02/107-0

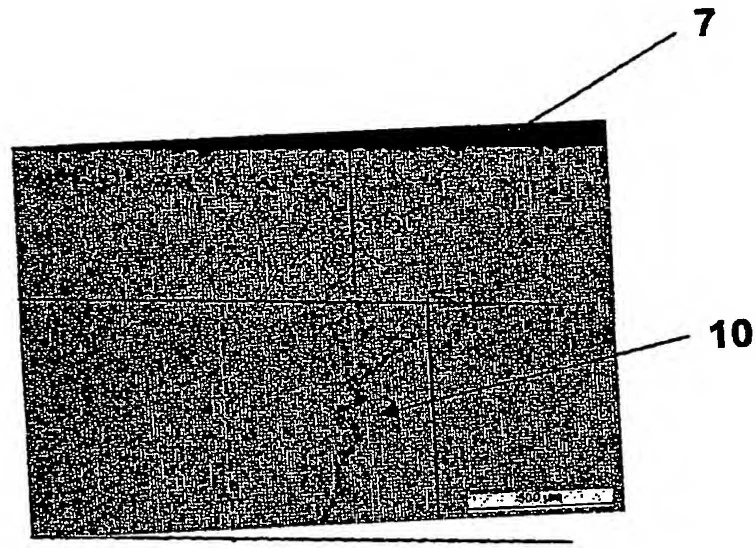

Fig. 6